University of Saskatchewan
Department of Physics and Engineering Physics
Physics 128.3 – Contemporary Physics
Final Examination

Time : 3 hours — Apr 21st, 2003

Circle your Instructor's Name :

D. Degenstein — J.E. Morelli

Student's Name: (Print) ______________________________________

Student Number: ______________________

Note : One 8.5 × 11 inch formula sheet is allowed.
Please answer the questions in the spaces provided.
Please show enough work to convince the marker you understand the material.
The back of each sheet may be used but please indicate that you have done so.
An extra blank sheet has been included in places where it may be required.
All questions are **NOT** allocated the same marks.
The assigned mark for each partial question is in parentheses near the answer space.

Good Luck!

1)	/ 12	2)	/ 14
3)	/ 14	4)	/ 15
5)	/ 12	6)	/ 12
7)	/ 14	8)	/ 16
9)	/ 18		
TOTAL:		/ 127	

Name: ________________________________

1) A standing wave pattern on a string is described by:

$$y(x,t) = 0.040\sin(5\pi x)\cos(40\pi t)$$

where x and y are in meters and t is in seconds.

a) Determine the location of all nodes for $0 \le x \le 0.40$ m. ____________________ ***(2 marks)***

b) What is the period of the oscillatory motion of any (non-node) point on the string?

__________________________***(2 marks)***

c) What is the speed of each of the two traveling waves that interfere to produce this wave?

__________________________***(2 marks)***

d) What is the amplitude of each of the two traveling waves that interfere to produce this wave?

__________________________***(2 marks)***

e) At what times for $0 \le t \le 0.050$ s will all the points on the string have zero transverse velocity?

__________________________***(2 marks)***

f) If the string has a linear mass density of 7.2 g/m what is the tension in the string?

__________________________***(2 marks)***

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2) A pulse travels down a wire under tension. The wire has a mass density of μ and the tension is T = 0.70 N. The shape of the disturbance on the wire is described by f(x - 4t), a function of both position (in meters) and time (in seconds). The Figure 2.1 below is a snapshot of the pulse at time t = 3 s.

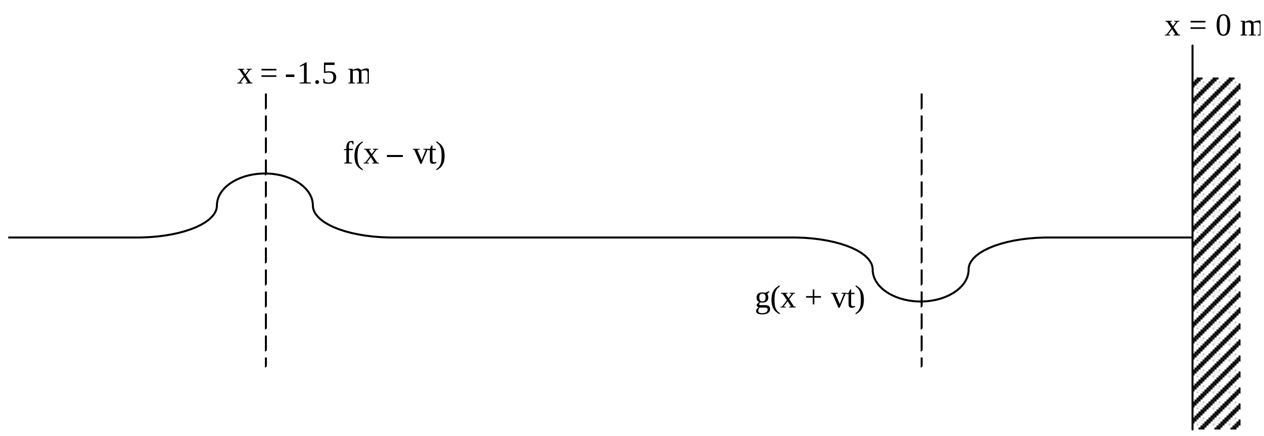

Figure 2.1

An identical pulse was seen 0.5 seconds earlier going down the wire past x = -1.5 m. It now has the shape given by g(x + vt).

a) What is the value v in g(x + vt)? ______________________***(2 marks)***

b) What is the mass density of the wire? ________________________***(2 marks)***

c) At what x value is the trough of g(x + vt)? ___________________________***(2 marks)***

d) What is the first time after t = 3 s that there will be no disturbance on the wire? _________________________***(2 marks)***

e) How much power is instantaneously transferred from the left to the right side of the x = -1.0 m point at t = 3 s? _______________________***(2 marks)***

Now assume that the other end of the wire is fixed to a second wall at x = -2m. Also assume that at t = 3 s, f(x – 4t) and g(x + vt) above are traveling down the wire.

f) When is the next time the wire will be in the exact same position as it is now? _________________________***(2 marks)***

g) What are the possible wavelengths and frequencies of the standing waves that could be produced on this wire? ______________________***(2 marks)***

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3) Use the two mass and spring system shown in Figure 3.1 below.

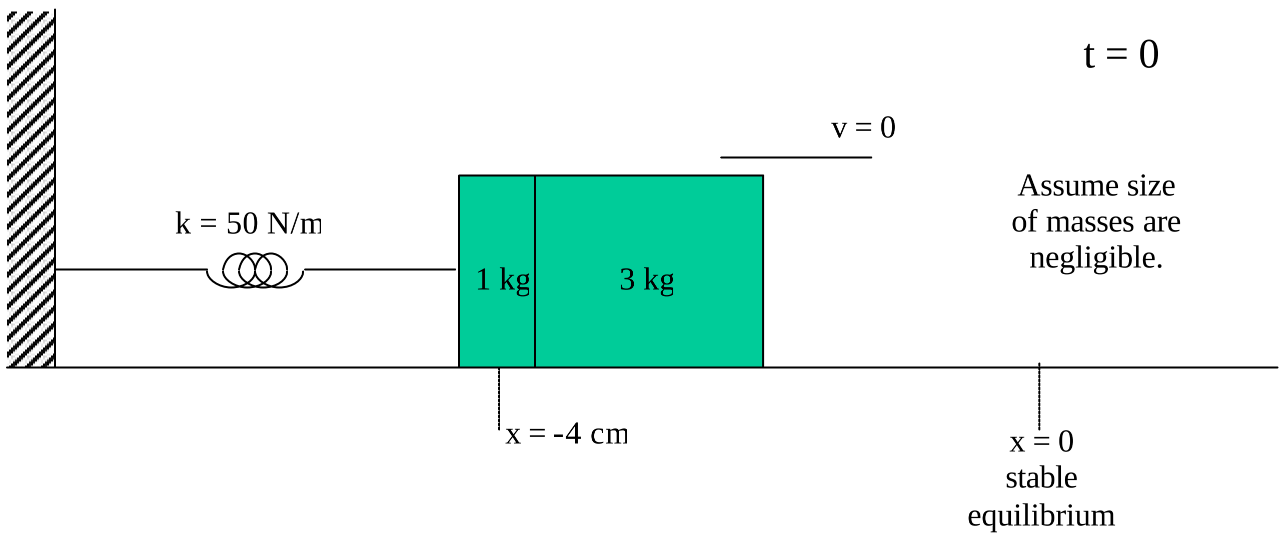

Figure 3.1

Note: the 3 kg mass is not attached to the 1 kg mass so they separate when the 1 kg mass feels a force in the negative x-direction.

a) Where does the 3 kg block separate from the 1 kg block? ___________________________***(2 marks)***

b) How fast is the 3 kg block going when it separates? _________________________***(2 marks)***

c) How much energy is in the two mass and spring system at t = 0 just before it is released?

_________________________***(2 marks)***

d) How much energy is in the one mass and spring system the first time it crosses x = 0?

_________________________***(2 marks)***

e) How much energy is in the oscillating system at t = 12 s? ___________________________***(2 marks)***

f) At what frequency (in Hertz) does this system oscillate? ____________________________***(2 marks)***

g) In the equation $x = A\cos(\omega t + \phi)$ that describes the motion of the oscillating block what is A?

_________________________***(2 marks)***

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Name: ______________________________

4) Two sinusoidal waves, identical except for phase, travel in the same direction along a string and interfere to produce a resultant wave given by:

$$y'(x,t) = y_1(x,t) + y_2(x,t) = (3.0\,\mathrm{mm})\cos(20x - 4.0t + 0.820\,\mathrm{rad})$$

with x in meters and t in seconds.

a) What is the wavelength of the two waves? ___________________________***(2 marks)***

b) What is the phase difference between the two waves? ________________________***(2 marks)***

c) What is the amplitude of the two waves? ____________________________***(2 marks)***

A student holds a tuning fork oscillating at 256.0 Hz. He walks towards a wall at a constant speed of 6.0 km/hr. The speed of sound in air is 330 m/s.

d) What beat frequency does he observe between the tuning fork and its echo?

_________________________***(4 marks)***

e) How fast must the student walk away from the wall to observe a beat frequency of 5 Hz?

_________________________***(5 marks)***

5) An asteroid is observed to be moving directly towards Earth at a speed of 0.70c. When the asteroid is 60 light-days away from the Earth a spaceship is launched from Earth directly towards the asteroid at a speed of 0.85c. After reaching the asteroid, the astronauts attempt to destroy the asteroid before it hits Earth. Assume that the arrival of the ship does not alter the asteroid's velocity.

a) Draw and completely label a spacetime diagram of the events and trajectories as viewed in the Earth's rest frame. ____________________________***(6 marks)***

b) As measured from Earth, how long does it take until the ship reaches the asteroid? _________________________***(2 marks)***

c) As measured by an astronaut on the spaceship, how long does it take until the ship reaches the asteroid? _______________________***(2 marks)***

d) After reaching the asteroid, how long do the astronauts have to destroy the asteroid before it hits Earth? _________________________***(2 marks)***

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6) Rocketman Bob is in his spacecraft zooming away from the Earth at a constant velocity. He is a bit of a scientist so he is passing the time by doing muon decay experiments. He sees a muon decay in 5×10^{-6} s and because he knows the muon takes 2.9×10^{-6} s to decay when it is at rest with respect to an observer he knows how fast it is moving. Earthman Bob, back at home on Earth with his high-powered telescope, notes that this exact same muon took 7×10^{-6} s to decay.

a) How fast is the muon going in Rocketman Bob's reference frame?

_________________________***(2 marks)***

b) How fast is the muon going in Earthman Bob's reference frame?

_________________________***(2 marks)***

c) How fast is Rocketman Bob moving in Earthman Bob's frame?

_________________________***(2 marks)***

d) How much spacecraft distance does the muon think it travels during its life?

_________________________***(2 marks)***

e) How much spacecraft distance does Rocketman Bob think the muon travels?

_________________________***(2 marks)***

f) How much spacecraft distance does Earthman Bob think the muon travels?

_________________________***(2 marks)***

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7) A proton with a rest energy of 938 MeV is accelerated to a velocity that is 0.90c. It then collides with another proton that is stationary.

a) What is the total energy of the two-proton system as measured in the lab frame?

______________________________***(2 marks)***

b) What is the total momentum of the two-proton system as measured in the lab frame?

______________________________***(2 marks)***

c) How much kinetic energy is in the two-proton system? This kinetic energy can be used to make particles and anti-particles during the collision process. ___________________________***(2 marks)***

d) How much more energy would the moving proton require to accelerate it to a speed of 0.95c?

______________________________***(2 marks)***

e) If during the collision of this $\beta = 0.95$ proton with the stationary proton, two 115 nm photons were produced, how much kinetic energy is available to make particles?

______________________________***(2 marks)***

f) To be considered relativistic the total kinetic energy of an object must be of the same order of magnitude as its rest energy. How fast must an object be traveling if it is to have a kinetic energy that is one half of its rest energy? ___________________________***(2 marks)***

g) Consider the following fusion reaction:

$$^{1}H + ^{12}C \rightarrow ^{13}N$$

The mass of Hydrogen is 1.007825 u, the mass of Carbon-12 is 12.000000 u, and the mass of Nitrogen-13 is 13.005739 u. How much energy is released by this reaction?

______________________________***(2 marks)***

8) A hydrogen atom in the n = 3 orbital level absorbs a photon with a wavelength of 200 nm.

a) What is the energy of the photon? ________________________***(2 marks)***

b) What is the momentum of the photon? ___________________________***(2 marks)***

The following questions refer to the electron in its final state.

c) What is the kinetic energy of the electron? _______________________***(2 marks)***

d) How much momentum does this electron have? _________________________***(2 marks)***

e) Is the electron still bound to the atom? ___________________________***(2 marks)***

f) What is the deBroglie wavelength of the electron? _______________________***(2 marks)***

g) What is the deBroglie frequency of the electron? ________________________***(2 marks)***

h) What is the relativistic correction factor γ for this electron? ______________________***(2 marks)***

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9) The electron of a hydrogen atom initially in the $n' = 4$ orbital drops down to the ground state by emitting a photon.

Before the transition:

a) What was its energy? _________________________ ***(2 marks)***

b) What was its orbital radius? __________________________ ***(2 marks)***

c) What was its orbital velocity? ________________________ ***(2 marks)***

d) What was its orbital period? __________________________ ***(2 marks)***

e) How much energy is required to rip the electron from the atom?

_________________________ ***(2 marks)***

During the transition:

f) What wavelength of photon was emitted? ___________________________ ***(2 marks)***

g) How much energy did the atom lose? ________________________ ***(2 marks)***

After the transition:

h) How much energy is required to rip the electron from the atom?

_________________________ ***(2 marks)***

i) What is the difference in mass between a single ground state hydrogen atom and the sum of its parts?

_________________________ ***(2 marks)***

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